

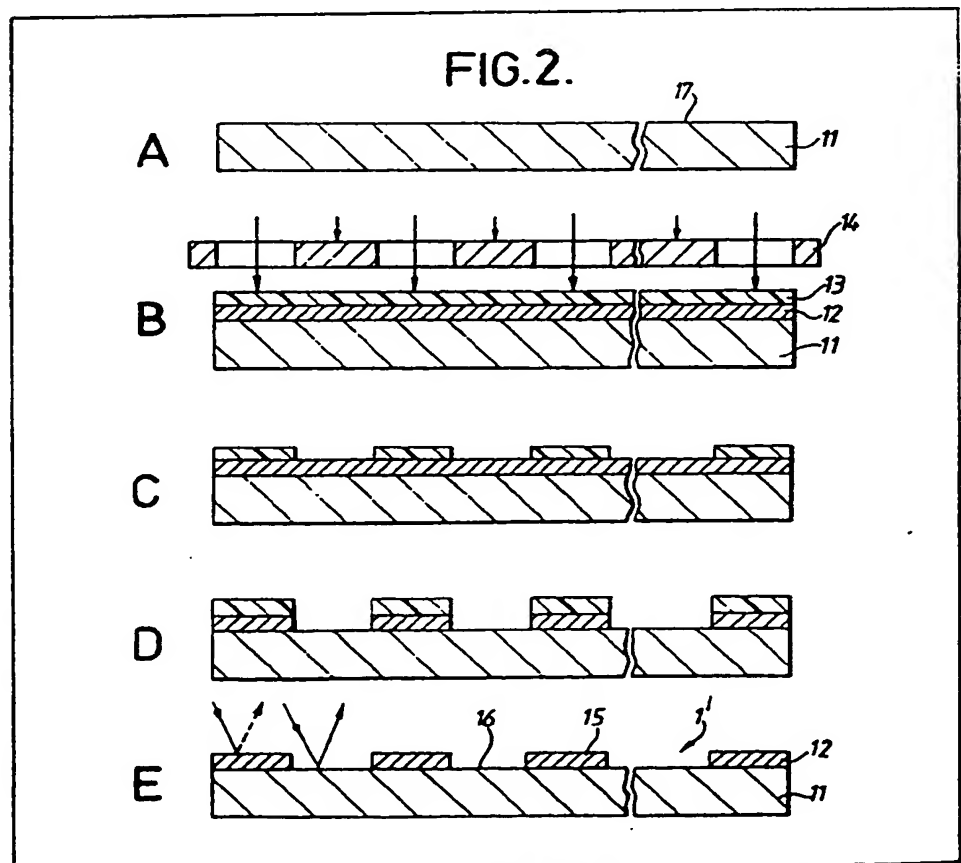
(12) UK Patent Application (19) GB (11) 2 072 850 A

(21) Application No 8105226
 (22) Date of filing 19 Feb 1981
 (30) Priority data
 (31) 56/021393
 (32) 22 Feb 1980
 (33) Japan (JP)
 (43) Application published
 7 Oct 1981
 (51) INT CL³
 G01B 5/02 3/04
 (52) Domestic classification
 G1M 11 1A2 1H
 (56) Documents cited
 None
 (58) Field of search
 G1M
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(54) Metal scale for an electronic measuring instrument

(57) A metal scale 1', for an electronic measuring instrument is made by forming a non-reflecting thin film 12 on a mirror-finished surface of a metal base 11. A photoresist film 13 is then applied onto the thin film 12, is irradiated with light through a mask 14, and developed. The photoresist film 13 is removed at portions that are to be engraved, the thin-film portions

12 thus exposed then being engraved by etching to provide light-reflecting graduations 16, without attacking the mirror-finished surface of the metal base 11. The remaining photoresist film 13 is then removed, so that the exposed thin-film surfaces 12 will serve as light-absorbing graduations 15. The metal scale 1' which is produced by this method is free from the development of side etches, whilst its light-reflecting graduations 16 show excellent durability.



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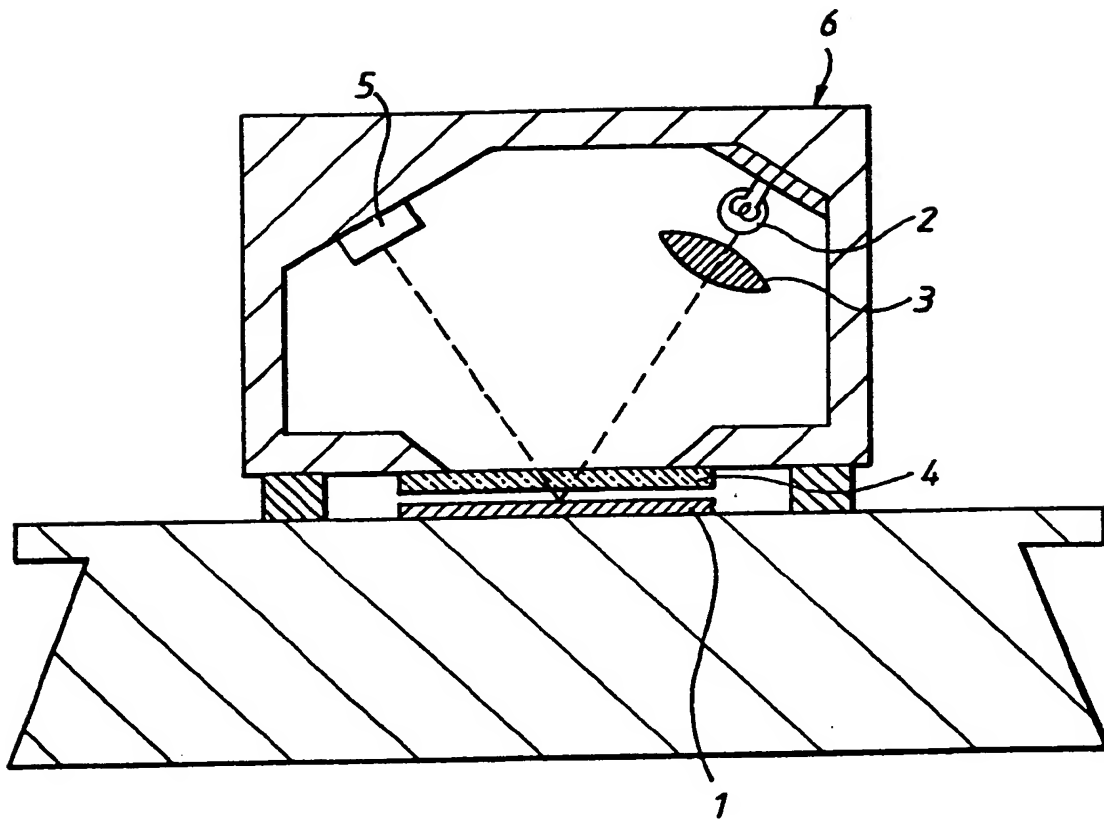


FIG.1.

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FIG.2.

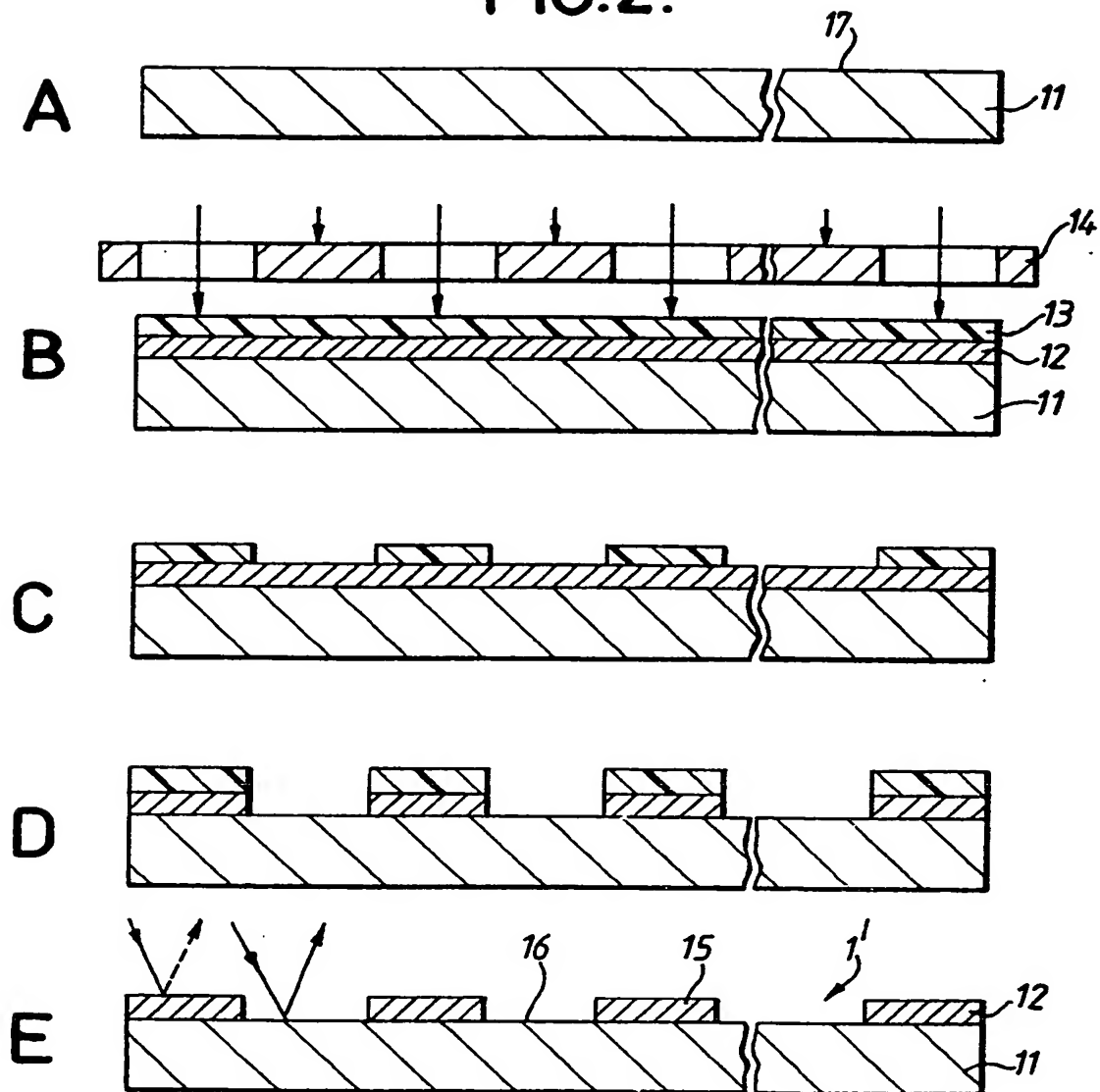
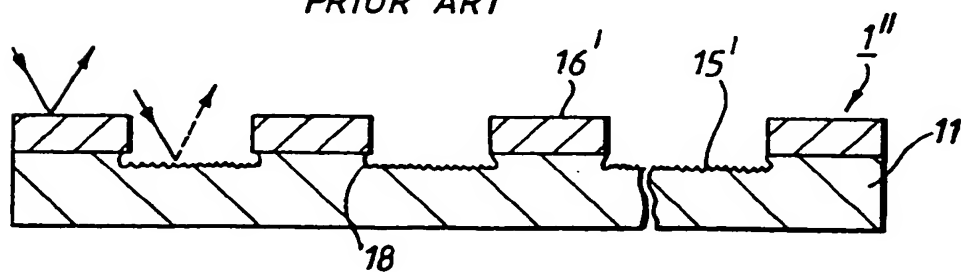


FIG.3.

PRIOR ART



SPECIFICATION

Metal scale for an electronic measuring instrument

This invention relates to a metal scale for an electronic measuring instrument of the type which measures the relative movement between two points, or which determines the distance between two such points. The invention also relates to a method of making such a metal scale.

An electronic measuring instrument of this type is shown in Fig. 1. The electronic measuring instrument has a metal scale 1, which is provided on one of two relatively-movable objects. The scale 1 has alternate light-absorbing graduations and light-reflecting graduations. The electronic measuring instrument also has a detector 6, which has a light source 2, a collimator lens 3, a photoelectric cell 5 and an index scale 4. The index scale 4 is provided with alternate light-transmitting graduations and light-absorbing graduations. The detector 6 is positioned on the side of the other object in such a way that the graduated surface of the index scale 4 is in close opposition to the graduated surface of the metal scale 1. In this instrument, the light beam (indicated by the dashed line) from the light source 2 is changed into a parallel light beam by the collimator lens 3. The parallel light beam is directed onto the index scale 4 and the metal scale 1. The light reflected by the light-reflecting graduations of the metal scale 1 is received by the photoelectric cell 5, which detects the modulation of the light received, this modulation resulting from relative movement of the index scale 4 and the metal scale 1. The corresponding voltage change produced by the cell 5 is converted by an A.C./D.C. converter, whose output leads to an indicator, such as a digital indicator (not shown), which gives a reading showing the relative movement of the two objects.

Fig. 3 of the accompanying drawings shows a typical metal scale 1" used with measuring instruments of this type. The scale 1" consists of light-reflecting graduations 16' and light-absorbing graduations 15'. The light-reflecting graduations 16' are made of a highly-reflective metal adhered on a metal base, and the light-absorbing graduations 15' are formed, from the surface of the metal base, by etching and roughening the surface. With this scale 1", the incident light is regularly reflected by the light-reflecting graduations 16', and is irregularly reflected by the light-absorbing graduations 15'. This causes different brightnesses between the light-reflecting graduations 16' and the light-absorbing graduations 15'.

Such a conventional metal scale is produced as follows. First, a metal with a high reflectivity (such as chromium, silver, gold or aluminium) is adhered onto the surface of a lapped metal base by, for example, plating or vacuum deposition, to a thickness of about 0.5 to 2 μm to form a mirror surface. Then, a photo-resist film is formed on the mirror surface, and the film is irradiated with light

through a photo-mask, the photo-mask having an image of the graduations that are to be put on to the scale. The irradiation film is then developed; after which the portions from which the photoresist film has been removed are subjected to etching by any known method. During the etching step, the photoresist-covered-portions are protected to form light-reflecting graduations. The etching step corrodes the portions of the light-reflecting film between the light-reflecting graduations, this corrosion reaching the base metal of the scale. Thus, the surface of the base metal is roughened to form light-absorbing graduations (dark portions) where the light is irregularly reflected.

Another method of producing such a metal scale consists of lapping the surface of a metal base to form a highly reflective surface (instead of employing a highly reflective metal), applying a photoresist film thereto, and engraving and roughening the surface of the scale to form dark portions in the same manner described above.

Using these conventional methods, the light-reflecting graduations are formed by plating a relatively great thickness of metal. Therefore, if a soft metal (such as gold) is used, the light-reflecting graduations have very little resistance to abrasion. Use of silver or copper, on the other hand, presents a problem with regard to resistance against corrosion.

Another serious disadvantage of the conventional methods is that the light-absorbing graduations are formed by roughening the metal base of the scale. This means that good light-absorbing graduations can only be obtained when the surface of the base metal is sufficiently roughened. However, if the etching is effected under conditions severe enough to attain the sufficient degree of roughening, serious side etches 18 will develop as shown in Fig. 3. These side etches 18 make it impossible to obtain the clear brightness boundary between the light-reflecting graduations and the light-absorbing graduations, which is necessary to provide the required light modulation. Furthermore, the development of side etches tends to cause the edges of the light-reflecting graduations to peel off, and this makes it difficult to form graduations of fine widths. For this reason, it is virtually impossible, with the known methods, to form scales having graduation widths of less than 10 μm .

Thus, conventional metal scales tend to cause distortions in the signal waveforms when used in the measuring instruments. This makes it difficult to split the signal waveform into multiple portions and, hence, conventional metal scales cannot facilitate accurate measurement.

In recent years, there have been developed etching methods which utilise an electron beam, a laser beam, an ionic beam, or a plasma beam, in an attempt to produce scales having graduation widths less than 10 μm , without giving rise to the above-mentioned defects. All of these methods, however, require bulky and expensive facilities,

and are not suitable for producing elongate scales having lengths of from several decimetres to several metres.

A scale has been proposed in which a thin film of chromium is formed on a glass base. Then, the chromium film is removed by etching to leave graduations, such that the etched portions permit light transmission, and the portions on which the chromium film is left do not permit light

transmission. With this scale, the defect of side etches is diminished, and a clear boundary is obtained between the portions which permit the transmission of light and the portions which do not permit light transmission.

However, such a scale employing glass as a base is principally used for detecting light which has been transmitted through the scale graduations, and is not suitable for detecting the light that is reflected by the scale graduations.

Thus, when a glass-based scale is used, an emission lamp is placed on one side of the scale, while an index scale and a photoelectric cell are placed on the other side of the scale. Then, the glass scale and the index scale are caused to move relative to each other, and the modulation in the intensity of the transmitted light through the two scales is electrically detected by the photoelectric cell, to give an indication of the amount of relative movement of the scales. Therefore, a scale of this type is not applicable to measuring instruments having a lamp and a photoelectric cell element on the same side of the scale.

The aim of the invention is to provide a metal scale which is free from side etches at the engraved portions, thereby providing clear boundaries between the light-reflecting graduations and the light-absorbing graduations, which has graduations whose widths are more finely spaced, and whose light-reflecting graduations are of excellent durability.

The present invention provides a metal scale for an electronic measuring instrument of the type which measures the relative movement between two points, or which determines the distance between such two points, the metal scale comprising a metal base having alternate light-reflecting graduations and light-absorbing graduations, wherein the light-reflecting graduations are formed on a mirror-finished surface of the metal base, and the light-absorbing graduations are made from a thin non-reflecting or light-absorbing film, the light absorbing graduations being formed on the mirror-finished surface and having predetermined intervals and widths.

Preferably, the thin non-reflecting or light-absorbing film is made of MgF_2 , SiO_2 , Cr_2O_3 or Ce_2O_3 , the metal base of the scale is made of stainless steel, and the thin non-reflecting or light-absorbing film has a thickness in the range of from 200 Å to 2000 Å.

Advantageously, the graduate width (that is to say, the width of the light-reflecting graduations and/or the width of the light-absorbing graduations) is less than 10 microns. Preferably,

the graduate width is less than 2 microns. The length of the scale may be greater than several decimetres.

The invention also provides a method of making a metal scale for an electronic measuring instrument which measures the relative movement of two points, or which determines the distance between such two points, the method comprising the steps of forming a mirror-finished surface on a metal base to be graduated; forming a thin non-reflecting or light-absorbing film on the mirror-finished surface; forming a photoresist film on said thin film; irradiating the photoresist film with light through a mask; developing the photoresist film; removing the photoresist film at portions to be engraved; engraving the thin film portions thus exposed, by etching, without attacking the mirror-finished surface of the metal base, thereby forming light-reflecting graduations; and removing the remaining photoresist film, thereby exposing said thin film portions which serve as light-absorbing graduations.

Advantageously, the surface of the metal base is mirror-finished to a surface roughness which is finer than JIS 0.25 (which corresponds to 0.2 μm in ISO ten-point height).

Preferably, a mixture of ammonium cerium nitrate and hydrogen peroxide solutions is used as a corrosive agent for effecting the etching.

The invention will now be described in greater detail, by way of example, with reference to Fig. 2 of the accompanying drawings, the five parts (A to E) of which are cross-sectional views illustrating the steps of making a metal scale according to the present invention.

Referring to the drawings, Fig. 2E shows a metal scale 1' made by the method of the present invention. The metal scale 1' consists essentially of light-reflecting graduations 16 and light-absorbing graduations 15. The light-reflecting graduations 16 are made up of a lapped plane 17 of a metal base 11, and the light-absorbing graduations 15 are adhered onto the lapped plane 17. Accordingly, the light-reflecting graduations 16 are formed from etched portions, unlike conventional metal scales, and so the scale 1' is essentially free of side etches.

A method of making the metal scale 1' will now be described. Generally, stainless steel is employed as a metal scale base 11, and the surface thereof is lapped (see Fig. 2A) to form a mirror plane of finer than JIS (Japanese Industrial Standard) 0.25 (corresponding to 0.2 μm in ISO ten-point height), or preferably finer than JIS 0.1S (corresponding to 0.1 μm in ISO ten-point height). A reflection-preventing film or a light-absorbing film 12 of, for example Cr_2O_3 , MgF_2 , SiO_2 or Ce_2O_3 is formed on the mirror surface by, for example, vacuum plating, chemical plating or electric plating. The reflection-preventing film 12 may also be formed by any other suitable substance such as an electrically non-conductive substance or a semiconductor substance, provided that it does not reflect the light irradiated thereon, and it is susceptible to the etching. As will be mentioned

later, the reflection-preventing film 12 should be as thin as possible; provided that it ensures sufficient prevention of light reflection, as well as sufficient adhesive strength. In the case of Cr_2O_3 , for example, the thickness should be in the range of from about 200 Å to 2000 Å. Then, an ordinary photoresist film 13 (see Fig. 2B) is formed on the surface of the reflection-preventing film 12 by, for example, coating. A mask 14, which corresponds to the required graduation pattern, is placed over the photoresist film 13, and is irradiated with light in the direction of the arrows. Then, the irradiated portions of the photoresist film 13 are sensitised and developed (see Fig. 2C). After this, the portions from which the photoresist film 13 have been removed are etched using a corrosive agent such as a mixture of ammonium cerium nitrate and hydrogen peroxide solutions, which dissolves the material of the film 12, but which does not attack the stainless steel. Thus, portions of the reflection-preventing film 12 are dissolved completely to form the light-reflecting graduations 16 (see Fig. 2D), the lapped surface of the metal base 11 being free from attack. Finally, the photoresist film 13 left on the reflection-preventing film 12 is removed, to form the light-absorbing graduations 15 (see Fig. 2E).

Instead of using a mixture of ammonium cerium nitrate and hydrogen peroxide solutions, it is also possible to remove the reflection-preventing film 12 by using other corrosive agents whose composition, concentration, and corrosion time are selected to suit the metal base 11 and the material of the reflection-preventing film 12. Even where the metal base 11 is relatively easily corrosible, the corrosion of the lapped surface can be minimised, since the reflection-preventing film 12 is very thin.

The metal scale 1' thus obtained does not develop side etches, and therefore has graduations having very clear brightness boundaries. This is because the light-reflecting graduations 16 are formed on the portions of the base 11 which have been subjected to etching (in contrast to the conventional methods). In other words, etching is effected not to form the light-absorbing graduations (as is the case with conventional methods of scale formation), but simply to remove the thin reflection-preventing film 12, which has a thickness of the order of angstroms. Therefore, the etching step can be carried out under very mild conditions. Moreover, since a corrosion-resistant material is used as the base metal, the development of side etches can be minimised. Furthermore, the light-absorbing graduations 15 are not formed by roughening the metal base 11, but are composed of a material which itself is capable of preventing light reflection. Consequently, the metal scale 1' gives more distinct contrast between its light-reflecting graduations 16, and the light-absorbing graduations 15 than is possible with known metal scales.

Another advantage of the invention is that the scale 1' can have graduation widths of as fine as

about 2 μm , which is quite astonishing when compared with the graduations widths of conventional scales. Furthermore, owing to the greater contrast in brightness of the graduations 15 and 16 of the metal scale 1' it is easier to use the multiple electric signals to give accurate read-outs, as compared with conventional metal scales.

Yet another advantage of the metal scale 1' is that its light-reflecting graduations 15 have an excellent resistance to wear and damage, since they are made of a corrosion-resistant metal, and are formed by etching at a level lower than the light-absorbing graduations 16.

CLAIMS

1. A metal scale for an electronic measuring instrument of the type which measures the relative movement between two points, or which determines the distance between such two points, the metal scale comprising a metal base having alternate light-reflecting graduations and light-absorbing graduations, wherein the light-reflecting graduations are formed on a mirror-finished surface of the metal base, and the light-absorbing graduations are made from a thin non-reflecting or light-absorbing film, the light-absorbing graduations being formed on the mirror-finished surface and having predetermined intervals and widths.

2. A metal scale as claimed in claim 1, wherein the thin non-reflecting or light-absorbing film is made of MgF_2 , SiO_2 , Cr_2O_3 or Ce_2O_3 .

3. A metal scale as claimed in claim 1 or claim 2, wherein the metal base of the scale is made of stainless steel.

4. A metal scale as claimed in any one of claims 1 to 3, wherein the thin non-reflecting or light-absorbing film has a thickness in the range of from 200 Å to 2000 Å.

5. A metal scale as claimed in any one of claims 1 to 4, wherein the graduate width (that is to say, the width of the light-reflecting graduations and/or the width of the light-absorbing graduations) is less than 10 microns.

6. A metal scale as claimed in claim 5, wherein the graduate width is less than 2 microns.

7. A metal scale as claimed in any one of claims 1 to 6, wherein the length of the scale is greater than several decimetres.

8. A metal scale substantially as hereinbefore described with reference to, and as illustrated by, Fig. 2E of the accompanying drawings.

9. A method of making a metal scale for an electronic measuring instrument which measures the relative movement of two points, or which determines the distance between such two points, the method comprising the steps of forming a mirror-finished surface on a metal base to be graduated; forming a thin non-reflecting or light-absorbing film on the mirror-finished surface; forming a photoresist film on said thin film; irradiating the photoresist film with light through a mask; developing the photoresist film; removing the photoresist film at portions to be engraved; engraving the thin film portions thus exposed, by

etching, without attacking the mirror-finished surface of the metal base, thereby forming light-reflecting graduations; and removing the remaining photoresist film, thereby exposing said thin film portions which serve as light-absorbing graduations.

10. A method as claimed in claim 9, wherein the surface of the metal base is mirror-finished to a surface roughness which is finer than JIS 0.25

10 (which corresponds to $0.2 \mu\text{m}$ in ISO ten-point height).

11. A method as claimed in claim 9 or claim 10, wherein a mixture of ammonium cerium nitrate and hydrogen peroxide solutions is used as a corrosive agent for effecting the etching.

12. A method of making a metal scale substantially as hereinbefore described with reference to Fig. 2 of the accompanying drawings.

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